Watershed Management Plan
for
New Brooklyn Lake

April 2004

Prepared for:

Camden County, New Jersey

Prepared By:

Urban Engineers, Inc. and **F. X. Browne, Inc.**

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Executive Summary

In 2003, Camden County contracted with Urban Engineers, Inc. to conduct lake and watershed studies of nine Camden County Lakes, including New Brooklyn Lake. Urban Engineers and F. X. Browne, Inc. conducted watershed assessments at each lake, including water quality analyses, bathymetric surveys, macrophyte mapping, GIS mapping, nonpoint source problem area watershed investigations, and the development of management plans for each of the study lakes. The New Brooklyn Lake study was conducted between July 2003 and March 2004.

New Brooklyn Lake is located on Great Egg Harbor River, which drains to Great Egg Harbor on the Atlantic Ocean.. In 1992, 129 miles of the Great Egg Harbor River and its tributaries were designated into the National Wild and Scenic Rivers System. The lake is approximately 13 acres in size. The watershed is located primarily in Gloucester, Winslow, and Berlin Townships in Camden County, New Jersey. The shoreline of New Brooklyn Lake is well vegetated and largely undeveloped, and the lake supports a healthy population of aquatic and wetland plants. The watershed is mostly undeveloped with only 28 percent of the watershed in residential and commercial land use. Greater than half of the watershed consists of forested land and wetlands (55 percent), which is commonly recognized as providing a natural filter for pollutants from the stormwater runoff.

Water quality monitoring results indicate that New Brooklyn Lake is borderline eutrophic. The total phosphorus concentrations, ranging from 50 to 65 *ug/l*, exceed the EPA criteria of 25 *ug/l* for eutrophic lakes. According to pollutant budget unit areal loadings, approximately 6,251 pounds per year of phosphorus enters New Brooklyn Lake from nonpoint sources. Chlorophyll a concentrations, a measure of algal biomass, were low, ranging from 1.0 to 6.8 *ug/l*. The EPA criterion for eutrophic lakes is 7 *ug/l*; therefore, New Brooklyn Lake was mesotrophic with respect to chlorophyll a during the 2003 growing season. Since the lake is so shallow, Secchi disk readings were not accurate as the Secchi disk could be seen on the bottom of the lake during several of the sampling events. The lake remained well oxygenated during the 2003 growing season, and the phytoplankton (algae) numbers were not excessive.

New Brooklyn Lake is filling in with sediment. This is causing the lake to become shallower and to fill up with macrophytes (aquatic plants). Wetland vegetation is encroaching on the upstream portion of the lake. Nutrient and sediment loads from the watershed are accelerating the eutrophication process. If this process is allowed to continue, New Brooklyn Lake will eventually become a marsh wetland instead of a lake. Based on the sediment thickness mapping, New Brooklyn Lake contains 23,000 cubic yards of unconsolidated sediment. If Camden County wants to maintain New Brooklyn Lake as an open water system, the lake should be dredged within three to five years to remove this unconsolidated sediment. In addition, the New Brooklyn Lake dam survey (conducted by others) indicated the dam is in poor condition and needs to be repaired.

Nonpoint source watershed investigations were conducted to detect potential problem areas and help determine watershed management recommendations. During the field investigations, several stormwater detention basins and concrete channels were observed that could be updated and retrofitted with stormwater BMPs that use natural vegetation to treat and infiltrate stormwater. Untreated urban stormwater from impervious areas such as parking lots and roads is a source of nutrients and sediments to New Brooklyn Lake. In addition, several areas of eroded shorelines were observed that would benefit from streambank stabilization and riparian buffer restoration. Sediments from eroding shorelines are accelerating the eutrophication process in New Brooklyn Lake.

Other watershed management recommendations include nuisance waterfowl management at Berlin Park, site development erosion and sedimentation control enforcement, continued water quality monitoring, and the development of a public education program. A summary of project costs and implementation schedule is provided in Sections 6.4 and 6.5 of this plan.

1.0 Introduction

In July 2003, Camden County retained Urban Engineers, Inc. and its subcontractor, F. X. Browne, Inc., to conduct lake and watershed studies of Cooper River Lake, Evans Pond, Hopkins Pond, New Brooklyn Lake, Pillings Lake, and Silver Lake. This project is part of a larger project to evaluate and prepare management plans for nine Camden County Lakes. Three lakes within the County – Peter Creek Lake, Newton Lake, and Haddon Lake – were studied in 2002.

The Camden County Lake Study was performed following accepted scientific methods that are described in Appendix A. F. X. Browne, Inc. collected water samples at New Brooklyn Lake on July 30, August 13, August 27, and September 10, 2003. A macrophyte survey, bathymetric survey, and watershed investigations for nonpoint source problem areas were also conducted during the fall of 2003. Stream monitoring was not performed at New Brooklyn Lake since the tributaries were located in wetland areas that were inaccessible for sampling. Water quality sampling methodology is described in Appendix A. A lake ecology primer is provided in Appendix B, and the water quality, phytoplankton, and zooplankton data for New Brooklyn Lake are provided in Appendix C.

2.0 Lake and Watershed Characteristics

New Brooklyn Lake is a man-made lake located near the headwaters of the Great Egg Harbor River, which drains to the Atlantic Ocean near Ocean City in Cape Map County, NJ. In 1992, 129 miles of the Great Egg Harbor River and its tributaries were designated into the National Wild and Scenic Rivers System. The lake is approximately 13 acres in size with a drainage area of 14,471 acres. During the 2003 growing season, the lake had no floating algae and a healthy amount of macrophytes (aquatic plants). The shoreline of New Brooklyn Lake is well vegetated and largely undeveloped. Much of the immediate lake shoreline and upper watershed consists of wetland areas. The wetlands most likely help to filter pollutants before they reach the lake, which helps protect the lake from the adverse effects of human activities.

Dam at New Brooklyn Lake

2.1 Lake Morphology

The morphometric characteristics of New Brooklyn Lake are presented in Table 1.1. New Brooklyn Lake is relatively shallow, with a maximum depth of 3 feet. The New Brooklyn Lake watershed, shown in Figure 2.1, is 14,471 acres.

Table 1.1 Morphometric Characteristics of New Brooklyn Lake	
Lake Surface Area	12.5 acres
Average Depth	1.6 feet
Maximum Depth	3.0 feet
Lake Volume	6.6 Million Gallons
Watershed Area (excluding lake area)	14,471 acres
Watershed Area to Lake Area Ratio	1,200:1

The lake watershed to surface area ratio is 1,200:1, which is extremely high. High watershed area to lake surface area ratios typically indicate that watershed management practices may not have a significant effect on the water quality of the lake. In-lake measures may be needed to improve lake water quality. This is not to say that watershed management practices should not be implemented; however, for water quality improvements to be most cost-effective, both in-lake and watershed practices should be considered.

The New Brooklyn Dam, a concrete gravity dam capped with stone, is located at the southern end of New Brooklyn Lake on the Great Egg Harbor River. Although the dam was certified to be in safe condition during the most recent inspection (July 2001), some deterioration was noted. In particular, the stone capping has fallen off of the two weirs and some deterioration of the concrete in the weirs and the upstream dam face is occurring. Trees and vegetation have grown up along the spillways, which are accelerating the deterioration of the dam. Some erosion was noted along the abutments on the west side of the dam. Dam repairs were recommended in the July 2001 certification report and should be implemented.

Figure 2.1 – New Brooklyn Lake Watershed Map

2.2 Benefits and Recreational Uses

2.2.1 Present Uses

The New Brooklyn Lake watershed is located primarily in Gloucester, Winslow, and Berlin Townships. The lake itself is easily accessible from heavily populated areas via the Atlantic City Expressway. A County park is located at the southern end of the lake in Winslow Township. The park has an attractive boardwalk nature trail, a beach, softball field, basketball court, playgrounds, outdoor amphitheater and pavilion, in-line hockey court, bike path, canoe launch, and picnic areas. The lake is used for canoeing and fishing, with reportedly good bass and pickerel fisheries.

2.2.2 Impairment of Recreational Uses

The water quality in New Brooklyn Lake is fairly good, and canoeing and fishing uses have not been significantly impaired to date. However, New Brooklyn Lake is filling in with sediment. This is causing the lake to become shallower and to fill up with macrophytes (aquatic plants). Wetland vegetation is encroaching on the upstream portion of the lake. Nutrient and sediment loads from the watershed are accelerating the eutrophication process. If this process is allowed to continue, New Brooklyn Lake will eventually become a marsh wetland instead of a lake.

2.3 Lake Bathymetry

A bathymetric survey was conducted by in November 2003. The survey was conducted using a Trimble GPS Pathfinder Pro XRS, a survey rod, and a boat. The outline of the lake was delineated using the GPS unit and recording location information around the perimeter of the entire lake. Water depth measurements, sediment thickness measurements, and location readings were taken along 21 transects. At each measurement location, the survey rod was lowered into the water to the top of the sediment and the depth was recorded. The survey rod was then pushed through the unconsolidated sediments to the hard bottom of the lake and that depth was also recorded. The difference between the depth to the top of the sediments and the depth to the hard bottom is the sediment thickness at that point. At each location, GPS location coordinates were recorded. All information collected in the field was stored in a data logger.

GIS and AutoCADD software were used to create a water depth map and a sediment thickness map based on the collected data. The volume of water and the volume of sediment in the lake were then calculated using LandCAD software. The bathymetric (water depth) map for New Brooklyn Lake is provided in Figure 2.2, and the sediment thickness map for New Brooklyn Lake is provided in Figure 2.3. Based on the sediment thickness mapping, New Brooklyn Lake contains approximately 23,000 cubic yards of unconsolidated sediment. The average sediment thickness is 1.1 feet, and the maximum sediment thickness is 4.3 feet.

Figure 2.2– New Brooklyn Lake Water Depth Map

Figure 2.3 – New Brooklyn Lake Sediment Thickness Map

2.4 Watershed Characteristics

2.4.1 Topography and Geology

The New Brooklyn Lake Watershed is 14,471 acres in size and relatively oval in shape as shown in Figure 2.1. The watershed is located in the southern end of Camden County just south of the Borough of Berlin, NJ. The lake is located on the Great Egg Harbor River which generally flows southeast through Camden and Atlantic Counties. Camden County is located in the coastal plain physiographic province of New Jersey. The geology consists of sedimentary rock from the cretaceous period, largely clay, sand, and glauconitic marl. Lands in Camden County are generally gently sloping plains with a slope range of 0 to 5 percent.

2.4.2 Soils

The soils in the New Brooklyn Lake Watershed consist primarily of soils in the Aura-Downer association and other loamy sand soil types, as shown in Figure 2.4. The majority of these soils are well-drained, and have the potential to be highly erosive although the slopes are mainly gentle. Wetland soils from the Muck Alluvial association are found along the floodplain of the Great Egg Harbor River. Table 2.1 shows characteristics of the most predominant soil types in the watershed; soil types that make up less than five percent of the watershed are included in the Other category.

Table 2.1
New Brooklyn Lake Watershed Soils*

Soil Name	Soil Abbreviation	Slope	Erosion Potential	Percentage of Watershed
Atison Sand	AtsA	0-2 %	Not highly erodible	8.1 %
Aura Loamy Sand	AucB	0-5%	Potentially highly erodible	7.2 %
Aura Sandy Loam	AugA, AugB	0-2, 0-5%	Potentially highly erodible	7.3 %
Downer Loamy Sand	DocB, DocC	0-5, 5-10%	Potentially highly erodible	19.1 %
Lakewood Sand	LasB, LasC	0-5, 5-10%	Potentially highly erodible	4.9 %
Manahawkin Muck	MakAt	0-2%	Not highly erodible Frequently flooded	9.4 %
Woodstown and Galloway Loamy Sand	WOUB	0-5%	Not highly erodible	5.5 %
Other				38.5 %

* Data from USDA NRCS Soil Survey Geographic database, July 2003

Figure 2.4 –New Brooklyn Lake Watershed Soils

2.4.3 Land Use

Land uses in the New Brooklyn Lake watershed are presented in Table 2.2 and Figure 2.5. National Land Cover Data satellite (30-meter Landsat thematic mapper) data with base data from the early 1990s were used in ArcGIS to obtain land use information for the New Brooklyn Lake watershed. The watershed is mostly undeveloped with only 28 percent of the watershed being residential and commercial. Greater than half of the watershed consists of forested land and wetlands (55 percent), which probably helps filter pollutants from the stormwater runoff entering New Brooklyn Lake. However, the heavily trafficked road immediately adjacent to the lake most likely does contribute nutrients and pollutants directly to the lake.

Table 2.2
New Brooklyn Lake Watershed Land Use

Land Use Category	Area (acres)	Percent (%)
Open Water	64	0.4
Residential	3,454	23.9
Commercial/Industrial	590	4.1
Forest	5,889	40.7
Agricultural	2,277	15.7
Recreational	86	0.6
Wetlands	2,111	14.6
Total	**14,471**	**100**

Figure 2.5 – **New Brooklyn Lake Watershed Land Use**

3.0 Water Quality and Biology

Water quality samples were collected during the 2003 growing season at New Brooklyn Lake as described in Appendix A. A lake ecology primer is provided in Appendix B, and the water quality, phytoplankton, and zooplankton data for New Brooklyn Lake are provided in Appendix C. The collected samples were preserved as necessary, and placed in a cooler for transport back to the F. X. Browne, Inc. New Jersey certified laboratory in Marshalls Creek, Pennsylvania. The lake samples were analyzed for total suspended solids, pH, total phosphorus, dissolved reactive phosphorus, TKN, nitrate-nitrite nitrogen, ammonia nitrogen, chlorophyll a, phytoplankton, and zooplankton. Dissolved oxygen and temperature profiles were measured in the field and a Secchi disk reading was measured on each sampling date. The results are discussed below.

3.1 Water Quality

The results of the water quality monitoring program for New Brooklyn Lake are presented in Table 3.1. The results indicate that New Brooklyn Lake is eutrophic with respect to phosphorus. The total phosphorus concentrations, ranging from 50 to 65 *ug/l*, exceed the EPA criteria for eutrophic lakes of 25 *ug/l*. Dissolved reactive phosphorus concentrations were high as well. Dissolved reactive phosphorus is the nutrient most readily used by phytoplankton for food, so this indicates that phytoplankton were probably not present in large enough numbers to consume the nutrient. The organic nitrogen concentrations in New Brooklyn Lake were somewhat high, but the inorganic nitrogen levels were very low. Total suspended solids concentrations were fairly low, indicating that large amounts of algae were probably not present.

Chlorophyll a concentrations, a measure of algal biomass, were low, ranging from 1.0 to 6.8 *ug/*l. The EPA criteria for eutrophic lakes is 7 *ug/l*; therefore, New Brooklyn Lake was mesotrophic with respect to chlorophyll a during the 2003 growing season. The Secchi disk transparency was very low (unfavorable) and was below the EPA criteria of 2.0 meters for eutrophic lakes during the two sampling events when readings were not visible on the bottom. However, since New Brooklyn Lake is so shallow, the Secchi disk was on the bottom during two of the four sampling dates. This may have artificially lowered the transparency readings, making them unreliable. Total suspended solids were low in New Brooklyn Lake during the 2003 growing season.

It should be noted that the pH concentrations were very low for typical New Jersey lakes, falling into the acidic range. Most likely this imbalance is due to acidic water entering the lake from the numerous wetlands around the shoreline, and it may have helped deter the overgrowth of phytoplankton in the lake considering the abundance of nutrients.

Table 3.1 New Brooklyn Lake Water Quality Data		
Parameter	**Average Value**	**Range**
Total Suspended Solids (*mg/l*)	5.1	2.0 – 8.0
pH (*units*)	5.7	5.0 – 6.0
Total Phosphorus (*ug/l*)	60	50 - 65
Dissolved Reactive Phosphorus (*ug/l*)	20	15 - 24
Total Nitrogen (*ug/l*)	990	770 - 1190
Organic Nitrogen (*ug/l*)	710	570 - 860
Ammonia Nitrogen (*ug/l*)	< 1.0	<1.0
Nitrate-Nitrite Nitrogen (*ug/l*)	190	20 - 350
Chlorophyll a (*ug/l*)	4.6	1.0 – 6.8
Pheophytin (*ug/l*)	2.7	<0.1 – 6.1
Secchi Disk Transparency (*m*)	0.38	0.30 – 0.40

3.2 Phytoplankton and Zooplankton

Phytoplankton samples were collected four times during the 2003 growing season at New Brooklyn Lake. The phytoplankton density was low in New Brooklyn Lake during all four sam … ranged from 680 cells/mL on September 10th to 2 … the phytoplankton densities were low, the phytoplankton population was largely dominated by undesirable blue-green species during most of the 2003 sampling events. The predominant blue-green species was of the genus *Psuedoanabaena*. The diatom *Eunotia* was dominant during late August. Figure 3.1 shows the total and blue-green phytoplankton densities in New Brooklyn Lake on each sampling date during 2003.

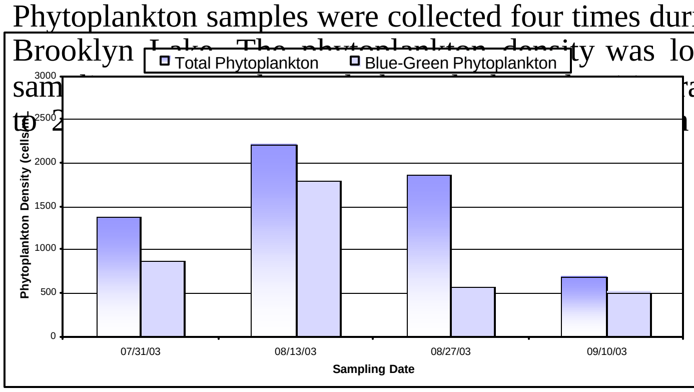


Figure 3.1 Phytoplankton Density in New Brooklyn Lake During the 2003 Growing Season

Phytoplankton biomass was low in New Brooklyn Lake during the 2003 growing season, and was not dominated by blue-green species, as shown in Figure 3.2. The total phytoplankton biomass ranged from 112 µg/L on September 10th to 3,608 µg/L on August 27th, 2003. The predominant species in terms of biomass were mainly in the diatom (Bacillariophyta) family. Green algae (family Chlorophyta) were also prevalent during late August. Diatoms and green algae are larger than blue-green species, and therefore tend to contribute more to overall phytoplankton biomass in the lake.

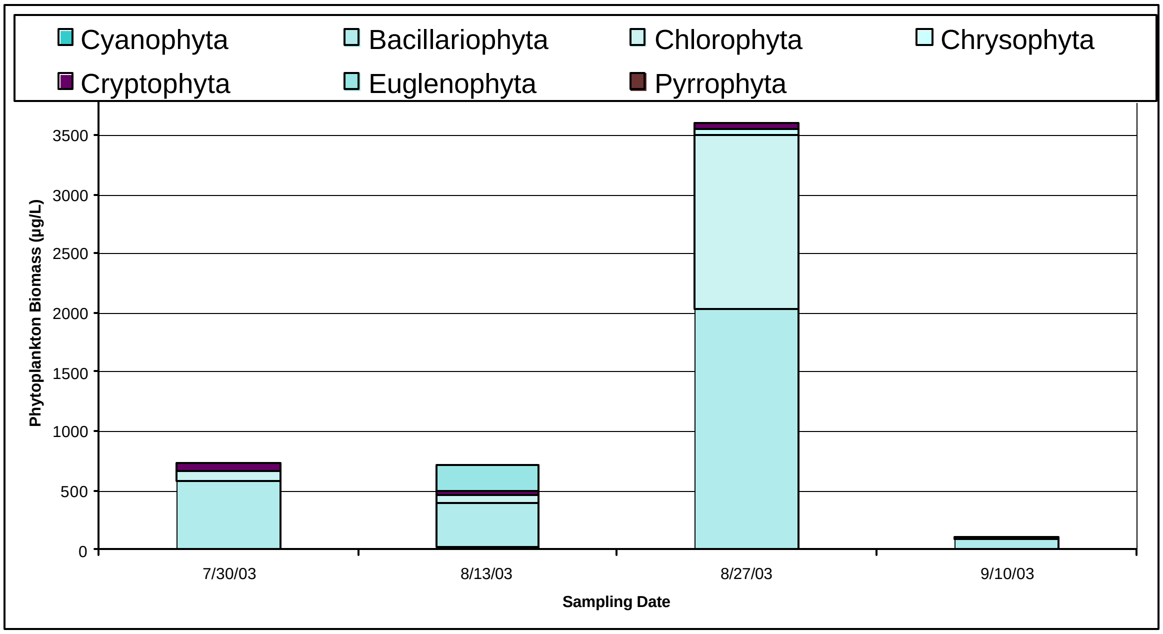


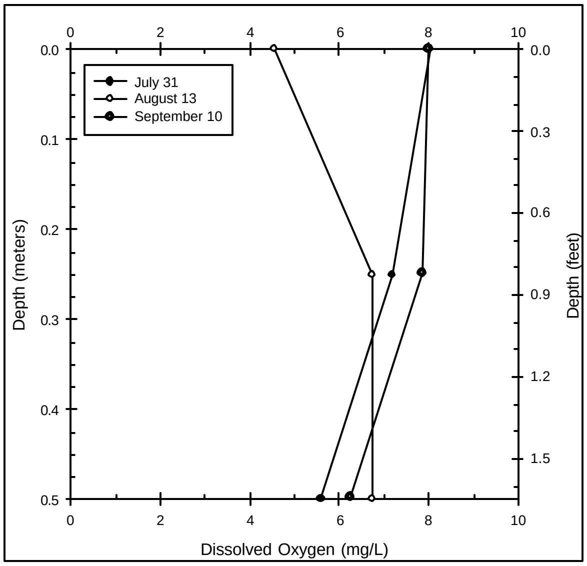
Figure 3.2 Phytoplankton Biomass in New Brooklyn Lake During the 2003 Growing Season

The low phytoplankton populations in New Brooklyn Lake during 2003 were most likely due to the large rain events during growing season flushing the phytoplankton out of the lake. Typically, eutrophic lakes such as New Brooklyn Lake have large algae populations during the summer months due to the availability of nutrients such as phosphorus and nitrogen that the algae use as food.

The zooplankton densities in New Brooklyn Lake during the 2003 growing season were low. Zooplankton densities were dominated by rotifers in July and September, and by copepods and cladocerans in August. Protozoans were also present during July in smaller numbers. The total zooplankton density ranged from 11.8 individuals/mL on August 27 to 64.8 ind/mL on September 10, 2003. Zooplankton biomass was also low, and was dominated by copepods and cladocerans, which are larger in size than rotifers. Zooplankton total biomass ranged from 1.5 ind/mL on July 31 to 47.6 ind/L on September 10, 2003. The mean length of crustaceans during 2003 averaged 0.28 mm. This may indicate an unbalanced fishery, with predominantly small panfish and fewer large game fish.

3.3 Dissolved Oxygen and Temperature

New Brooklyn Lake is very shallow (less than one meter deep) and was not thermally stratified during the 2003 growing season. Surface water temperatures ranged from 16.4 ºC on September 10 to 23.1 ºC on August 13, 2003. New Brooklyn Lake was generally well oxygenated during the 2003 growing season. Due to the lake's shallow nature, it most likely remains fairly well mixed throughout most of its depth from wind and waves. Figure 3.3 shows dissolved oxygen profiles for New Brooklyn Lake during the 2003 growing season, and Figure 3.4 shows the temperature profiles for New Brooklyn Lake during the 2003 growing season.



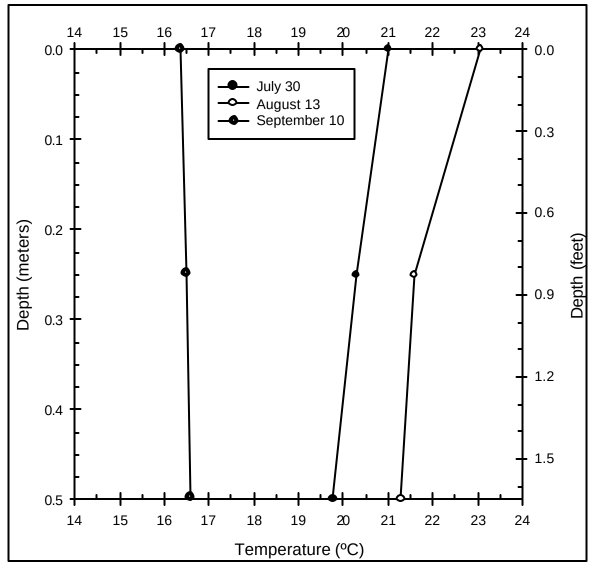


Figure 3.3 2003 Dissolved Oxygen Profiles for New Brooklyn Lake

Figure 3.4 2003 Temperature Profiles for New Brooklyn Lake

3.4 Trophic State Indices

As described in Appendix A, the Carlson's Trophic State Index is widely used to classify the trophic state or ecological condition of a lake. The Carlson's Trophic State Indices for New Brooklyn Lake are presented in Table 3.2

Table 3.2
Trophic State Indices for New Brooklyn Lake

Parameter	Index
Total Phosphorus	63
Chlorophyll a	45
Secchi Disk Transparency	N/A**

** Since two of the Secchi disk readings were on the bottom of the lake, and the remaining two were close to the bottom of the lake, the TSI for Secchi disk transparency is not a valid number.

New Brooklyn Lake is eutrophic for total phosphorus and mesotrophic for chlorophyll a. The transparency TSI in New Brooklyn Lake is not a valid number since the Secchi disk was at or very near the bottom of the lake during all of the readings. Overall, New Brooklyn Lake can best be classified as eutrophic.

3.5 Macrophytes

New Brooklyn Lake contains a moderate amount of macrophytes, although relatively few species were represented. The entire shoreline except for the beach areas was colonized by swamp loosestrife (*Decodon verticillatus*). Many areas of cattails (*Typha* spp.) and common reed (*Phragmites australis*) were also seen along the shore. Both of these species tend to form monocultures, sometimes outcompeting other native vegetation. Stands of coontail (*Ceratophyllum demersum*) and bladderwort (*Utricularia vulgaris*) were seen near each of the beach areas, and small amounts of duckweed (*Lemna* spp.) were scattered about the lake. Overall, the amount of macrophyte growth in New Brooklyn Lake is not considered excessive, although the coontail and bladderwort at the beach area can make swimming or wading undesirable. As the lake continues to become shallower, the macrophytes and wetland vegetation are likely to increase in number and areal coverage. A map of the macrophyte distribution in New Brooklyn Lake is provided in Figure 3.5.

C = Cattails (*Typha* spp.)
P = Common Reed (*Phragmites australis*)

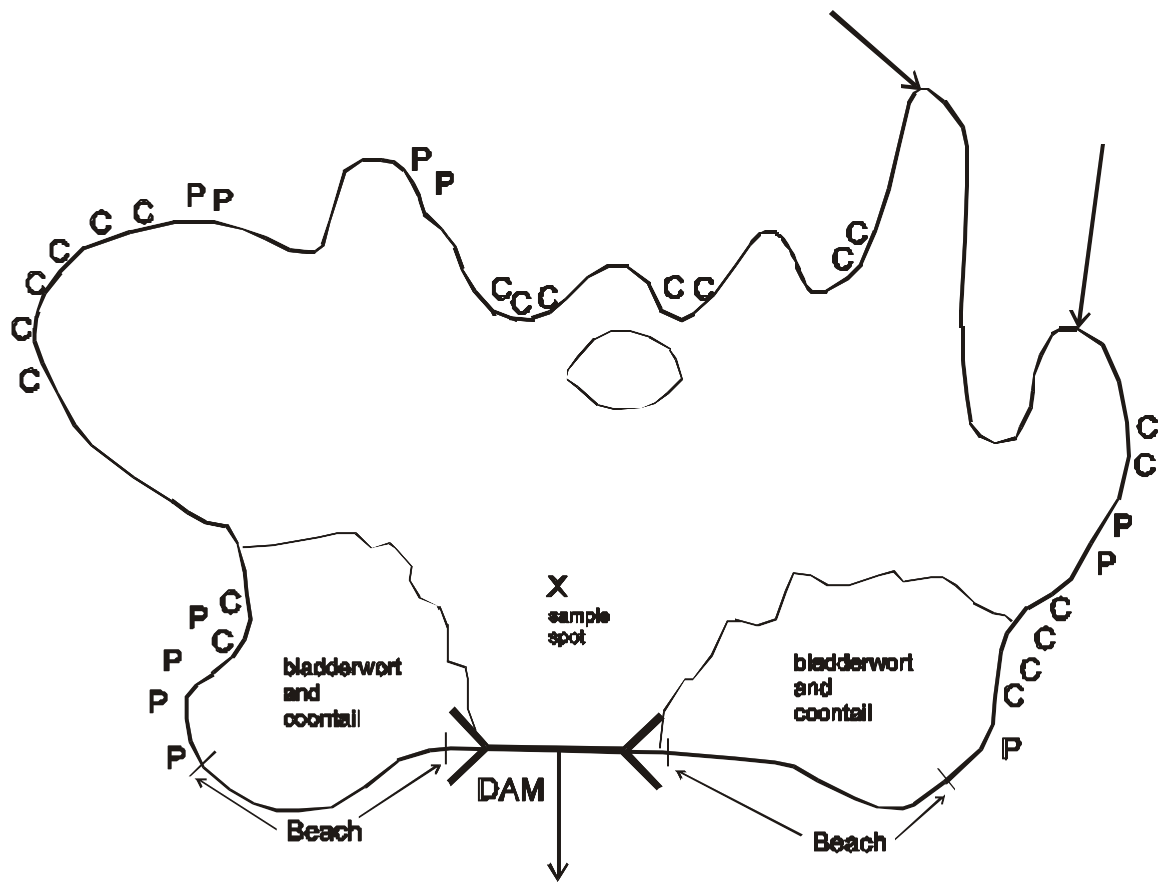


Figure 3.5	**Macrophyte Map of New Brooklyn Lake**

4.0 Pollutant Loadings

Both natural events, such as precipitation and runoff, and human activities, including agriculture, silviculture, and construction, can contribute pollutants to the lake system. Stormflow conditions typically contribute large quantities of water with relatively high pollutant concentrations over relatively short durations throughout a given study period, and are therefore a very significant portion of any pollutant budget. Baseflows typically contribute lower quantities of water with relatively low pollutant concentrations over relatively long durations throughout a given study period, which can also result in significant nonpoint source pollutant loadings.

Nonpoint source pollutant loadings for waterbodies can be assessed through a stream monitoring program, or through the use of the Unit Areal Loading (UAL) approach (U.S.EPA, 1980). The monitoring approach requires the acquisition of both streamflow and water quality data to all inlet (inflowing) streams during dry and wet weather periods. It also requires knowing the total amount of flow and the proportion of stormflow versus baseflow. The UAL approach is based on the assumption that different land use types contribute different quantities of pollutants through runoff.

The pollutant budget for the New Brooklyn Lake watershed was estimated using the Unit Areal Loading Method. Wet weather sampling was not conducted at New Brooklyn Lake since the tributaries were located in wetland areas that were inaccessible for sampling. Pollutant runoff coefficients were chosen based on field data and applicable literature data. A summary of the pollutant loads by land use type and totals are provided in Table 4.1.

Approximately 6,251 pounds per year of phosphorus enters New Brooklyn Lake from nonpoint sources. Since there are no point sources in the watershed, the total estimated phosphorus load to New Brooklyn Lake is 6,251 pounds per year. The total estimated nitrogen load to New Brooklyn lake is 46,004 pounds per year, and the total estimated sediment load to New Brooklyn lake is 2,399,040 pounds per year.

Table 4.1 Estimated Unit Areal Loadings for the New Brooklyn Lake Watershed				
Land Use (% Watershed/# Acres)	**Parameter**	**Runoff Coefficient (lbs/ac/yr)**	**Annual Pollutant Load (lbs/yr)**	**Percent of Total Load**
Undeveloped- Forested/ Wetlands (55.3%/8,000 acres)	Total Phosphorus Total Nitrogen Total Suspended Solids	0.25 2.00 100	2,000 16,000 800,000	32.0 34.8 33.3
Agricultural- Cropland, Pasture, Idle (hay) (15.7%/2,277 acres)	Total Phosphorus Total Nitrogen Total Suspended Solids	0.75 6.0 220	1,708 13,662 500,940	27.3 29.7 20.9
Residential- High/low density, Parkland (24.5%/3,540 acres)	Total Phosphorus Total Nitrogen Total Suspended Solids	0.5 3.25 200	1,770 11,505 708,000	28.3 25.0 29.5
Urban- Commercial, Industrial, Quarries (4.1%/590 acres)	Total Phosphorus Total Nitrogen Total Suspended Solids	1.3 7.5 660	767 4,425 389,400	12.3 9.6 16.2
Open Water * (0.44%/64 acres)	Total Phosphorus Total Nitrogen Total Suspended Solids		6 413 700	0.09 0.9 0.03
TOTALS – (100%/ 14,471 acres)	**Total Phosphorus Total Nitrogen Total Suspended Solids**		6,251 46,005 2,399,040	

* Pollutant loads are based on an average rainfall of 44 inches per year and pollutant deposition concentrations of 0.008 mg/L for phosphorus, 0.59 mg/L for total nitrogen, and 1.0 mg/L for total suspended solids.

5.0 Watershed Investigations

Watershed investigations to detect potential nonpoint source pollution problem areas were conducted in the New Brooklyn Lake watershed during December 2003. Table 5.1 provides field notes compiled during the watershed investigations and recommendations for BMPs that may help solve the problems. Figure 5.1 shows the location of each watershed problem area identified in Table 5.1.

5.1 Streambank Stabilization and Restoration

Streambank erosion is a problem on the Great Egg Harbor River passing through Berlin Park. Several outlet pipes are clogged, and sediment is collecting in the stream from eroded streambanks. Sediment that is eroded from streambanks is carried into New Brooklyn Lake during storm events, and the sediment eventually settles to the bottom of the lake. Trash and other debris are entering the stream at the park as well.

5.2 Urban Stormwater Management

During the field investigations, several stormwater detention basins and concrete channels were observed that could be updated and retrofitted with stormwater BMPs that use natural vegetation to treat and infiltrate stormwater, such as grassed swales and bioretention systems. It is apparent that stormwater runoff from impervious areas, such as parking lots and roads, is entering the streams untreated. This untreated urban stormwater is a source of nutrients and sediments to New Brooklyn Lake.

Concrete Channels Near New Brooklyn Lake

Road Runoff and Debris Being Channeled Directly into Stream Entering New Brooklyn Lake

5.3 Nuisance Waterfowl Control

Excessive numbers of waterfowl were noted on the Great Egg Harbor River at Berlin Park. Nuisance waterfowl can create major water quality problems for lakes and streams. The large numbers of waterfowl, mainly Canada geese and gulls, aggravate shoreline erosion problems by walking up and down the banks. The waterfowl droppings are also a problem and are a direct source of phosphorus, nitrogen, and bacteria to the stream and lake.

Nuisance waterfowl, inadequate riparian buffer, and eroded shorelines along the Great Egg Harbor River in Berlin Park

5.4 Riparian Buffer Restoration

Several areas in the watershed lack an adequate riparian buffer between roads, trails, and parking lots and the lake and its tributaries. The lack of a protective buffer allows stormwater carrying nutrients, sediment, trash, and other pollutants from the road surface to enter the water, and leaves the streambanks and shoreline unprotected from erosion.

Table 5.1 Field Notes and Recommendations New Brooklyn Lake Watershed		
Problem Area Number	**Field Notes**	**Recommendations**
1	New residential development. Large dirt piles; construction. Two stormwater basins. Farmland on opposite corner.	Erosion and Sedimentation Controls Possibly retrofit stormwater basins
2	Appears that existing surface water body was expanded for stormwater management.	Possibly retrofit stormwater basin
3	Concrete-lined channel connecting to swale along road.	Retrofit concrete channel to grassed swale
4	Berlin Park. Ugly surface water drainage channel from warehouse building to park. Lots of trash and debris. Outlet pipe is clogged. Stream through park is in poor condition. Eroded shorelines. Sediment deposition. Litter and debris. Many ducks and geese.	Retrofit drainage channel to grassed swale Clean up trash, clean out clogged pipe Streambank stabilization Plant riparian buffer (may help with nuisance waterfowl) Dredge sediments, if necessary, after stream restored Environmental education kiosk
5	Stream crossing. Blue Sky helicopter services – they seem to have let a hangar structure fall into stream. Stream itself is all right.	Remove hangar from stream
6	Stream crossing – no significant erosion.	
7	Great Egg Harbor River crossing. USGS gauge station. Stream appears to be in good condition and stable on both sides.	
8	New Brooklyn Lake Attractive lake with sandy beach/access area, although right next to a heavy-trafficked road. Some minor erosion gullies from road runoff. Lots of phragmites. Park continues along New Brooklyn Road – nicer access area with boardwalk and bench.	Stabilize gullies Enhance riparian buffer between road and lake Environmental education kiosk

Figure 5.1 – Nonpoint Source Pollution Problem Area Map

6.0 Recommended Management Plan

In developing a recommended management plan for New Brooklyn Lake, both in-lake management alternatives and watershed management alternatives were evaluated. The first priority in all management programs is to determine whether watershed management practices can be implemented to reduce the pollutants entering the lake. Because nonpoint source pollutants account for 100 percent of the nutrient and sediment loadings to New Brooklyn Lake, it is critical that lake restoration focuses on watershed controls.

During the development of the watershed management plan, the following criteria were used to evaluate the potential management alternatives:

Effectiveness:	how well a specific management practice meets its goal
Longevity:	reflects the duration of treatment effectiveness
Confidence:	refers to the number and quality of reports and studies supporting the effectiveness rating given to a specific treatment
Applicability:	refers to whether or not the treatment directly affects the cause of the problem and whether it is suitable for the region in which it is considered for application
Potential for Negative Impacts:	an evaluation should be made to ensure that a proposed management practice does not cause a negative impact on the pond ecosystem
Capital Costs:	standard approaches should be used to evaluate the cost-effectiveness of various alternatives
Operation and Maintenance Costs:	these costs should be evaluated to help determine the cost-effectiveness of each management alternative

The recommended management plan for New Brooklyn Lake is based upon the following: (1) lake water quality data, (2) watershed investigations, (3) estimated pollutant budgets, and (4) the goals as established by Camden County.

Recommended in-lake management alternatives for New Brooklyn Lake include dredging and dam restoration. Watershed management alternatives for New Brooklyn Lake include shoreline stabilization, streambank stabilization, waterfowl control, urban stormwater management, site development erosion and sedimentation control, and riparian corridor management. In addition, a public education program, water quality monitoring program, and institutional approaches are recommended.

The recommendations provided in this lake and watershed management plan will help the municipalities within the watershed to comply with the new EPA Stormwater Phase II Final Rule. MS-4 municipalities were required to submit an application to the NJDEP to be included in the General Phase II Stormwater Permit by March 2003 and will then be required to implement the following minimum control measures to reduce nonpoint source pollutants from stormwater runoff:

1. Public education and outreach
2. Public participation and involvement
3. Illicit discharge detection and elimination
4. Construction site runoff control
5. Post-construction runoff control
6. Pollution prevention and good housekeeping

The recommendations in this report cover most of these requirements including a well run public education program, storm sewer stenciling, identification of potential BMP retrofit areas to improve stormwater quality, and a more effective street sweeping program.

6.1 In-Lake Measures

6.1.1 Dredging

Although the macrophyte and algae growth in New Brooklyn Lake are not excessive, the lake is filling in with sediment. The lake contains an estimated 23,000 cubic yards of sediment that should be removed by dredging. Wetland vegetation is already encroaching on the northern end of the lake. While the wetlands act as a filter to pollutants entering the a lake and therefore improve the lake water quality, they are a sign that the lake is beginning to revert to a wetland marsh. If the sediment accumulation is allowed to continue without dredging, the entire lake will soon be considered a wetland and dredging permits will be extremely difficult, if not impossible, to obtain. If Camden County wishes to maintain New Brooklyn Lake as a lake with open water, they should plan to dredge the lake within the next three to five years.

Based on the amount of accumulated sediment, the size of the lake, and the likely difficulty in permitting and executing lake drawdown in this situation, hydraulic dredging is recommended for New Brooklyn Lake. Lake drawdown would not be required for hydraulic dredging. Sediment disposal could be accomplished by identifying a nearby area for a sediment disposal basin or using a sediment de-watering unit to avoid the need for construction of costly disposal basins. The de-watering unit only requires a small area for operation and can produce a de-watered sediment that is approximately seventy-five to eighty percent solids. The de-watering process relies on the use of an anionic polymer which quickly flocculates the dredge slurry. The clean water is released back into the lake and the de-watered solids accumulate in a pile near the de-watering units. The solids can later be transported to a proper disposal area, such as farm fields, or may possibly be sold as fill material. Any disposal areas must be approved by the NJ DEP.

A formal dredging feasibility study should be completed in order to obtain more precise bathymetric, hydrologic, and cost information. A pre-application meeting is required by the NJ DEP for dredging projects to discuss the project, determine what permits will be required for this specific project, and discuss potential disposal areas. Potential sediment disposal areas could include nearby parkland or horse farm fields, depending upon the chemical nature and quality of the sediments. Chemical testing of the lake sediments would be required to evaluate the disposal options, and should be conducted as part of the dredging feasibility study in close cooperation with the NJ DEP.

Dredging is only recommended in areas of the lake where boat traffic and other recreation has become impaired. Dredging is not recommended in areas where such recreational activities are not desirable, such as the edges of the lake and the shallower bays, since these well-vegetated, shallow areas offer excellent aquatic habitat for fish, reptiles, amphibians, macroinvertebrates, and wading birds. It is important to note that certain shallow vegetated areas are considered regulated wetlands and dredging of such areas may require wetland mitigation. Wetlands mitigation may be accomplished by replanting the dredged area with desirable native aquatic plant species, by stabilizing eroding shoreline areas, or by constructing wetlands in a desirable location around the lake. A formal wetlands survey by a qualified wetlands biologist should be completed for the entire project area during the early planning stages so that wetlands impacts are avoided or minimized.

Some of the problems associated with dredging include the disturbance of the benthic (lake bottom) community and the disturbance of both fishery nesting and refuge areas. Many of the residing aquatic organisms will be physically removed or smothered by the settling sediments in areas adjacent to the dredging operation. However, these problems are short-term, and the continued improvement of dredging equipment and dredging methods have helped to minimize these adverse impacts. The physical removal of lake sediments is often referred to as the "ultimate face-lift". Overall, the costs for dredging are high, but the benefits are long-term, as long as control measures are implemented to minimize the amount of sediment entering the lake. Sources of sediment and nonpoint source pollution within the watershed should be addressed in order to reduce the likelihood of future dredging projects.

6.1.2 Dam Restoration

The dam at New Brooklyn Lake is in poor condition and should be repaired. A 2001 dam inspection report recommends the following repairs:

1. Repair the weir structures,

2. Replace the stone capping over the top of the weir structures after repairs are complete,

3. Remove the trees and vegetation growing on the dam structure,

4. Clean and re-grout the joints of the stone capping on the dam structure, and

5. Stabilize the eroded areas around the abutment wing walls.

The repairs should be initiated promptly to prevent dam failure, which could result in the rapid loss of water in the lake and associated wetland system.

6.2 Watershed Controls

The water quality in New Brooklyn Lake is fairly good. Therefore, reducing nutrient and sediment loading from the surrounding watershed is imperative to maintain and potentially improve the water quality of the lake.

6.2.1 Shoreline and Streambank Stabilization

One of the most critical management practices to improve the New Brooklyn watershed is the stabilization of streambanks and shorelines. In particular, areas of erosion were observed on the Great Egg Harbor River where it flows through Berlin Park and along Cedar Brook Road near New Brooklyn Lake. Additionally, it is likely that other areas of streambank erosion exist along tributaries on private land that could not be inspected as part of this project. Soil erosion along streambanks is a major source of nonpoint pollution in watersheds. Certain nutrients as well as many other pollutants adhere to eroded soil particles and are introduced to the waterways. Lakes and reservoirs are particularly affected by nutrients associated with sediment loads. These large, still bodies of water serve as settling basins for the particulate matter that is transported by their contributory streams.

Restoration of eroded streambanks is a highly successful way to significantly reduce sediment and nutrient loadings to New Brooklyn Lake for a reasonable cost. By using bioengineering (vegetative) or a combination of bioengineering and structural engineering streambank stabilization techniques, the erosion problem is corrected while the stabilized streambank serves as a vegetative buffer and in many cases, a restored riparian corridor. The buffer along the stream reduces the quantities of sediments and nutrients that enter the stream via stormwater runoff. It is recommended that lower cost, bioengineering approaches be used wherever practical to stabilize the severely eroded streambank areas in the New Brooklyn Lake watershed noted on the nonpoint source problem area map.

6.2.2 Urban Stormwater Management

Over the past ten years, a number of stormwater best management practices have been developed to reduce the adverse water quality impacts associated with urbanization. Overall, stormwater control measures serve two distinct functions: (1) to reproduce pre-development hydrologic conditions, and (2) to provide pollutant removal capabilities. Historically, stormwater management has focused on reducing the frequency and severity of downstream flooding by reducing the peak discharge from post-developed sites. More recently, stormwater management has been redefined to include the removal of pollutants, thereby improving and protecting the quality of downstream waters.

Road Runoff causing erosion and entering New Brooklyn Lake untreated

Below is a list of stormwater management practices that were evaluated for urban areas in the New Brooklyn Lake watershed area. In developed areas, stormwater management should primarily focus on urban stormwater controls such as sand filters, water quality inlets, and infiltration structures. These stormwater controls do not require vast areas of land, and therefore can be integrated into existing urban settings. Camden County should target large parking lots that do not currently have stormwater facilities to implement these BMPs. The goal of these BMPs is to capture and treat the water quality design storm (1.25 inches of rainfall in a two hour period).

Urban Stormwater Controls

1. Sand Filters
2. Water Quality Inlets
3. Infiltration Trenches
4. Bioretention Systems
5. Buffer Strips (Filter Strips)

In areas of future development or redevelopment, stormwater management controls such as infiltration basins, extended detention basins, constructed wetlands, and buffer strips should be constructed or implemented. These stormwater control measures typically require larger tracts of land and therefore should be incorporated or designed as part of the land development planning process.

Other options for improving the water quality of stormwater runoff include:

- Camden County and the municipalities within the New Brooklyn Lake Watershed should evaluate street sweeping schedules. Increased street sweeping is recommended in the developed areas of the watershed, especially in the spring and summer months.

- Stormwater catch basins should be cleaned after major storm events or at least once every three months. Cooperation between Camden County, the local municipalities, and the New Jersey Department of Transportation is recommended for this task.

- Existing homeowners and business owners should be encouraged to direct roof runoff to dry pits or rain barrels to reduce the amount of stormwater that enters the storm sewer system. Using a rain barrel or cistern gives the homeowner the advantage of water use reduction by storing rain water for watering gardens or lawns during dry periods. B.t.i mosquito larvicide (sometimes called B.t.i. donuts) can be used to ensure that the rain barrels do not turn into mosquito breeding areas. These "donuts" are EPA-approved and readily available in hardware and gardening stores.

- Homeowners should be informed that if they dump household chemicals and other substances into storm sewers, these substances will end up in New Brooklyn Lake. Storm inlets should be stenciled to educate homeowners that anything that goes down the storm sewer eventually drains directly into the lake.

- Homeowners should be encouraged to wash cars and trucks on grassy areas, if possible, or use a commercial car wash. This practice will reduce the amount of phosphorus and detergent that runs down the driveway into a nearby storm sewer and eventually into New Brooklyn Lake.

- Leaf management is also important for reducing nonpoint source pollution in a developed watershed. A leaf management program should be evaluated or initiated to determine if there are ways to improve the program so that leaves do not end up in the street for a long period of time. If leaves are left in the street too long, nutrients leach from the leaves and are carried into the storm sewers and eventually into the lake with stormwater runoff. Encouraging or requiring homeowners to bag leaves in biodegradable bags is one possibility for improving the leaf management program.

Concrete channels within the watershed should be retrofitted with grassed swales or directed to stormwater practices that are designed to reduce peak flow velocities and infiltrate stormwater rather than allowing it to enter the stream directly. Concrete channels provide no stormwater treatment, and often allow stormwater to flow at high speeds, causing erosion at the stream outfall.

6.2.3 Nuisance Waterfowl Control

Canada Geese at New Brooklyn Lake

"Nuisance" waterfowl is a term frequently used to describe such flocks of birds that congregate on the shores of lakes and other water bodies year-round, eroding shorelines by frequently entering and exiting the water and contributing large amounts of nutrients to the water through their feces. Although most people enjoy seeing the birds, and many even feed them, the potential harm to lake water quality can be serious. The excessive bird feces can lead to algae blooms, accelerated eutrophication, depleted dissolved oxygen levels, and high bacteria levels in downstream waterbodies. These problems have a negative impact on the ecological balance of the water body, and can threaten other native species. Excessive numbers of waterfowl were observed at Berlin Park during the watershed investigations.

A range of options is available to discourage nuisance resident waterfowl populations, some more palatable to bird lovers than others. Geese can be chased away by dogs, loud noises, or visual deterrents. Geese can be excluded from congregating in certain areas via fencing or other barriers. Breeding can be minimized via egg addling. Geese can be gathered up and moved during the molting period. Some park and municipal managers have been known to scare off geese by shining lasers into their eyes at night. Many managers have resorted to gassing or shooting the geese. Other than the barriers and visual or audio deterrents, DEP permits are usually required for nuisance waterfowl management.

One of the most effective ways to discourage geese from congregating is to allow vegetation to grow up around the edge of a lake or stream. Geese prefer not to walk through long grasses or sedges to enter the water, so by maintaining a buffer area around the edge, the geese will look for another home. Vegetative buffers have the additional water quality benefit of filtering runoff from entering the water.

Camden County officials should work together with Berlin Borough officials to develop an acceptable and effective nuisance waterfowl management plan.

6.2.4 Riparian Corridor Restoration

Adequately vegetated or buffered streams remove pollutants from stormwater runoff. In addition to pollutant removal, stream buffers reduce water temperature, maintain stream flow during dry seasons, stabilize streambanks, decrease erosion potential, provide valuable wildlife habitat, provide improved in-stream aquatic habitat, provide flood control, and enhance the natural landscape by providing visually appealing "green belts." During the watershed investigations, several areas were identified that had inadequate riparian buffers. Riparian buffers should be enhanced wherever necessary in the New Brooklyn Lake watershed. Eroded areas of the streambanks should be stabilized as described in section 6.2.1, and a 50 to 75-foot buffer should be maintained along the entire stream channel. A multi-zone buffer provides the best protection, including a zone of native trees next to the water's edge, a zone of shrubs and "disturbed forest" beyond that where recreational activities can occur, and a third zone composed of dense grasses, broad-leaved herbaceous plants, and wildflowers extending outward from the stream. A more extensive riparian buffer will have the additional benefit of reducing nuisance waterfowl congregation. The buffer should be maintained by replacing poor growing vegetation, removing invasive plant species, and protecting the area from game animals such as whitetail deer.

6.2.5 Site Development Erosion and Sedimentation Pollution Control

During the watershed investigations in the New Brooklyn Lake watershed, an area of new residential development was observed with inadequate erosion and sedimentation controls in place (see Section 5). Nonpoint source pollution from site development may be very significant during earthmoving and construction activities. The potential for soil erosion is very high until the site is stabilized with permanent vegetative cover, and is further heightened when soils are "highly erodible" and on steep slopes. Typically, large-scale development projects receive greater attention with respect to the installation and maintenance of proper erosion and sedimentation pollution controls. However, smaller construction projects such as single-family residential sites in many cases lack proper erosion and sedimentation pollution controls. In fact, at many small construction sites, no erosion and sedimentation pollution controls are implemented.

The Camden County Soil Conservation District requires erosion and sedimentation pollution control plans for all earthmoving activities, large and small. Any disturbances greater than one acre require a National Pollution Discharge Elimination System permit from the New Jersey Department of Environmental Protection. Enforcement of erosion and sedimentation control at smaller sites is difficult due to the unsure timing of the actual earthmoving and the general lack of project information. However, erosion and sedimentation pollution control plans are just as important and should be enforced.

6.3 Other Programs

6.3.1 Public Education Program

The U.S. Environmental Protection Agency (EPA) and NJDEP actively encourage the development of environmental education programs by providing helpful literature, suggestions and funding sources. The U.S. EPA has funded education programs through the 314 Clean Lakes Program, the 319 Nonpoint Source Program and the Environmental Education Program.

An environmental education program should be developed for the New Brooklyn Lake watershed, and could include the following elements:

1. Develop and distribute a nonpoint source pollution awareness brochure,

2. Develop a watershed management program for presentation to local schools,

3. Develop and install a kiosk at Berlin Park and New Brooklyn Park detailing watershed protection efforts and things local citizens can do to protect the lake and watershed,

4. Write a fact sheet on watershed management for distribution at the kiosk and at local events, and

5. Conduct homeowner seminars and other environmental education programs to cover such topics as proper use of lawn and garden fertilizer, composting, leaf management, and the use of native vegetation in yards and gardens.

6.3.2 Water Quality Monitoring Program

A limited water quality monitoring program should be implemented both before and after watershed BMPs have been implemented to document water quality improvements. Annual monitoring of selected parameters (i.e. dissolved oxygen, total nitrogen, total phosphorus, chlorophyll a, and Secchi disk transparency) should be conducted in New Brooklyn Lake to document water quality changes in the lake. Sample collection could be done by volunteers or Camden County employees under the direction of a professional.

6.3.3 Institutional Practices

Camden County officials should establish a Waterways Team made up of County and Township officials, representatives from the Great Egg Harbor River Watershed Association, and other stakeholders identified by the County to work together to improve the water quality in New Brooklyn Lake. Recommended tasks that should be performed by the Waterways Team are as follows:

1. To evaluate existing subdivision ordinances, erosion and sedimentation control ordinances, and other ordinances for their applicability to the New Brooklyn Lake watershed area,

2. To determine if any of the above ordinances require revisions to further protect stream and lake water quality,

3. To assist in the coordination of all lake and watershed management activities,

4. To establish a "Watershed Watch" program to ensure that erosion and sedimentation controls are properly installed and maintained during and after construction activities, and to watch for bank and stream erosion,

5. To communicate watershed problems including the lack of compliance with municipal ordinances to the proper authorities, and

6. To assist in obtaining funds for the implementation of lake and watershed management best management practices.

The Waterways Team should evaluate the existing erosion and sedimentation control and stormwater control ordinances to ensure that these documents are effectively protecting the water quality in County streams and lakes. The Waterways Team should also evaluate the applicability of lawn fertilization and waterfowl feeding ordinances for the New Brooklyn Lake watershed.

In addition, for both existing and new development, the protection, development, and enhancement of stream buffers should be encouraged. The municipalities within the New Brooklyn Lake watershed should adopt a riparian stream conservation ordinance.

6.4 Implementation Costs

Implementation costs for the New Brooklyn Lake Watershed Management Plan will vary greatly depending on the size and locations of each BMP. Table 6.1 lists the various recommended BMPs, plus their approximate costs and priority rankings. Dredging is the highest priority BMP. The dredging feasibility study will provide a more accurate estimate of dredging costs. However, assuming that an acceptable disposal area can be found within 5 miles of the lake, and assuming that capping or covering the sediment is required, the estimated cost to dredge New Brooklyn Lake could range from $400,000 to $500,000, including design, permitting, and disposal. This cost may increase if the sediments are contaminated and must be disposed of in a hazardous waste landfill.

Streambank stabilization and riparian corridor restoration BMPs require maintenance for 1-2 years after installation, but the costs of maintenance are significantly less than the initial costs. Stormwater management BMPs require annual maintenance, but these costs are also much lower than the initial cost of the retrofit, and can usually be included in regular landscaping costs. The costs of water quality monitoring program can be reduced by the use of volunteers or County employees. The costs of the institutional BMPs will vary depending on the Township and the level of participation and commitment of the participants.

In order to implement the recommended management plan for New Brooklyn Lake, a plan of action is needed which involves identifying who will implement the program and how the program will be funded. Camden County should work with other members of the Waterways

Team to secure funding to implement the watershed management recommendations. The primary funding source for implementing items in the recommended management plan is the EPA's 319 Nonpoint Source Program. The 319 Nonpoint Source program is administered in New Jersey through the Department of Environmental Protection, and provides funds for watershed management projects and public education programs.

Table 6.1
Implementation Costs for New Brooklyn Lake Watershed BMPs

Type of BMP	Name of BMP	Cost of BMP	Priority Ranking
In-Lake	Dredging Feasibility Study	$15,000	High
In-Lake	Hydraulic Dredging	$850,000-900,000 including design and permitting	High
In-Lake	Dam Repair	**	High
In-Lake	Water Quality Monitoring	$3,000-$5,000 per year	Medium
Watershed	Waterfowl Management	$10,000, plus possible annual maintenance costs	Low
Watershed	Streambank Stabilization	$25-$75 per linear foot plus maintenance costs	High
Watershed	Riparian Corridor Restoration	$500 per acre plus maintenance costs	Medium
Watershed	Stormwater Management – Biorentention retrofit	$6.80 per cubic foot of water storage plus annual maintenance costs	Medium
Watershed	Stormwater Management – Grassed Swale retrofit	$5-15 per linear foot plus annual maintenance costs	Medium
Institutional	Site Development E&S Enforcement	Varies per Township	High
Institutional	Public Education Program	$20,000	Medium
Institutional	Waterways Team Development	N/A	High

** Determination of the cost of dam repairs is outside of the scope of this project, as the cost must be determined by the engineer in charge of dam reconstruction.

6.5 Implementation Schedule

If Camden County wants to maintain New Brooklyn Lake as an open water system, the lake should be dredged within three to five years to remove this unconsolidated sediment. A dredging feasibility study should be performed prior to lake dredging. The study will take approximately 3-4 months. Design and permitting for dredging projects typically takes about 6-9 months. In general, dredging is most detrimental to aquatic life in the spring and least detrimental in late summer/early fall.

In addition, repairs to the dam at New Brooklyn Lake are a high priority and should be implemented as soon as possible. The other recommended BMPs should be evaluated and implemented on an individual site basis as time and funding permits.

Appendix A
Methodology

1.0 Water Chemistry Methodology

Water samples were collected from each lake using a horizontal Van Dorn water sampler. Water chemistry samples were collected at 0.5 meter below the water surface. In addition, dissolved oxygen and temperature profiles were measured and Secchi disk readings were taken at the lakes on each sampling date. Zooplankton samples were collected by towing a plankton net through the water column. Dry weather grab samples were collected from the tributaries of each lake where tributary samples were collected by F. X. Browne, Inc. on the same dates that the lakes were sampled. Wet weather grab samples were collected from the tributaries by Urban Engineers.

The collected samples were preserved as necessary, and placed in a cooler for transport back to the F. X. Browne, Inc. New Jersey certified laboratory in Marshalls Creek, Pennsylvania. The lake samples were analyzed for total suspended solids, pH, total phosphorus, dissolved reactive phosphorus, TKN, nitrate-nitrite nitrogen, ammonia nitrogen, and chlorophyll a. The stream samples were analyzed for total suspended solids, pH, total phosphorus, dissolved reactive phosphorus, TKN, nitrate-nitrite nitrogen and ammonia-nitrogen.

1.1 TSS

The concentration of total suspended solids in a lake is a measure of the amount of particulate matter in the water column. Suspended solids are comprised of both organic matter (i.e. algae, bacteria, detritus) and inorganic materials (i.e. soil and clay particles). In most lakes, total suspended solids concentrations are less than 25 mg/L and can often be less than 10 mg/L. Lakes that receive significant amounts of erosion from stormwater runoff and those with high phytoplankton biomass usually have high total suspended solids concentrations.

1.2 pH

In lake ecosystems, changes in pH occur when phytoplankton use carbon dioxide during photosynthesis. Dissolved carbon dioxide reacts with water to form carbonic acid (H2CO3). When phytoplankton take up the carbon dioxide dissolved in the lake water during photosynthesis, it results in a decrease in the carbonic acid concentration and a consequent increase in pH. For this reason, the pH of surface waters is higher during an algal bloom than the pH of deeper water where phytoplankton (suspended microscopic plants) numbers are much lower.

1.3 Phosphorus

Phosphorus and nitrogen compounds are major nutrients required for growth of algae and macrophytes in lakes. The dissolved inorganic nutrients, dissolved reactive phosphorus, nitrate nitrogen, and ammonia nitrogen are regarded as the forms most readily available to support aquatic growth. In most lake systems, phosphorus is the limiting nutrient and therefore is the nutrient that usually controls the amount of aquatic plant growth (vascular plants and algae).

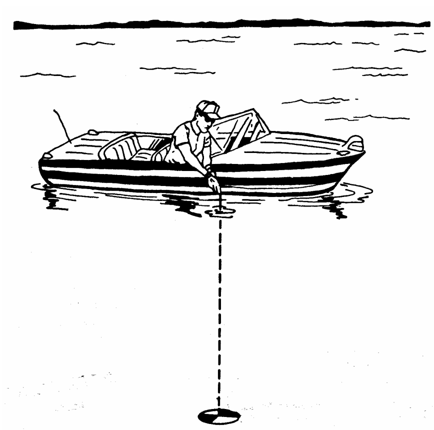
Total phosphorus represents the sum of all phosphorus forms, and includes dissolved and particulate organic phosphates from algae and other organisms, inorganic particulate phosphorus from soil particulates and other solids, polyphosphates from detergents, and dissolved orthophosphates. Soluble orthophosphates is the phosphorus form that is most readily available for algal uptake and is usually reported as dissolved reactive phosphorus, because the analysis takes place under acid conditions that can result in some hydrolysis of other phosphorus forms. Total phosphorus levels are strongly affected by the daily phosphorus loads that enter the lake. Soluble orthophosphates levels, however, are affected by algal consumption during the growing season.

1.4 Nitrogen

Nitrogen compounds are also important for algae and aquatic macrophyte growth. The common inorganic forms of nitrogen in water are nitrate ($N0_3$), nitrite ($N0_2$), and ammonia (NH_3). The form of inorganic nitrogen present depends largely on dissolved oxygen concentrations. Nitrate is the form usually found in surface waters, while ammonia is only stable under low oxygen conditions. Nitrite is an intermediate form of nitrogen that is unstable in surface waters. Nitrate and nitrite (total oxidized nitrogen) are often analyzed together and reported as $N0_3$+$N0_2$-N, although nitrite concentrations are usually insignificant. Total Kjeldahl nitrogen (TKN) concentrations include ammonia and organic nitrogen (both soluble and particulate forms). Organic nitrogen is easily determined by subtracting ammonia nitrogen from total Kjeldahl nitrogen. Total nitrogen is calculated by summing the nitrate-nitrite, ammonia, and organic nitrogen fractions together.

2.0 Transparency

The transparency of the water was measured in each of the lakes using a Secchi disk. Secchi disk transparency is an indirect measurement of the total amount of organic and inorganic turbidity in a lake that is measured using a 20 cm white and black patterned disk. The Secchi disk is lowered into the water until it is no longer visible, then raised slightly until it can just be seen. The Secchi disk transparency is the depth in meters recorded at that point. Observed Secchi disk values can range from a few centimeters in very turbid lakes to over 40 meters in the clearest known lakes. Although somewhat simplistic and subjective, this testing method probably best represents the conditions that are most readily visible to the common lake user. Secchi disk measurements were taken at the deepest point in the lake on each sampling event.



Secchi disk transparency is related to the transmission of light in water and depends on both the absorption and scattering of light. The absorption of light in dark-colored waters reduces light transmission. Light scattering is usually a more important factor than absorption in determining Secchi depths. Scattering can be caused by color, by particulate organic matter, including algal cells, and by inorganic materials such as suspended clay particles in water. Water transparency is widely used to classify the trophic state of a lake.

3.0 Chlorophyll a

Samples were collected for chlorophyll a analysis in each lake. A sample was collected from the photic zone of each lake using a Van Dorn sampler. The photic zone is the portion of the water column that receives enough light for the photosynthetic process to occur and for algae to live. The photic zone is considered to extend from the water surface to a depth that is two times the Secchi disk transparency. The water sample from each lake was transferred to opaque bottles, transported to the F. X. Browne, Inc. lab in Marshalls Creek, and treated to extract chlorophyll a from algae cells for analysis and determination of the chlorophyll a concentration. Chlorophyll a is the green pigment that all green plants use to convert sunlight to chemical energy during photosynthesis. Chlorophyll a constitutes about one to two percent of the dry weight of planktonic algae, so the amount of chlorophyll a in a water sample can be used as an indicator of phytoplankton (algae) biomass.

4.0 Phytoplankton and Zooplankton

Phytoplankton samples were collected at each lake by obtaining a water sample from the lake photic zone. Phytoplankton are microscopic algae that have little or no resistance to currents and are found free floating and suspended in open water. Their forms may be unicellular, colonial, or filamentous. As photosynthetic organisms (primary producers), phytoplankton form the foundation of the aquatic food web and are grazed upon by zooplankton (microscopic animals) and herbivorous, or plant-eating, fish.

A healthy lake should support a diverse assemblage of phytoplankton represented by a variety of algal species. Excessive phytoplanktonic growth, which typically consists of a few dominant species, is undesirable. Excessive growth can result in severe oxygen depletion in the water at night, when the algae are respiring (using up oxygen) and not photosynthesizing (producing oxygen). Oxygen depletion can also occur following an algal bloom when bacteria grow and multiply using dead algal cells as a food source. Excessive growth of some species of algae, particularly members of the blue-green group, may cause taste and odor problems, release toxic substances into the water, or give the water an unattractive green soupy or scummy appearance.

Planktonic productivity is commonly expressed by enumeration and biomass. Enumeration of phytoplankton is expressed as cells per milliliter (cells/mL). Biomass is expressed on a mass per volume basis as micrograms per liter (μg/L). Of the two, biomass provides a better estimate of the actual standing crop of phytoplankton in lakes.

What was previously referred to as blue-green algae (Cyanophyta) is now commonly referred to in the scientific literature as Cyanobacteria. Cyanobacteria are organisms that act like both algae, in that they contain chlorophyll and perform photosynthesis, and bacteria, in that their cell structure is similar to bacteria. In this report we refer to these organisms as blue-green algae from the taxa Cyanophyta since their primary role in lakes are similar to algae.

It should be noted that since phytoplankton populations tend to wax and wane throughout the year, a single sample from a lake or pond may not be indicative of the overall status of the lake with respect to algae. For example, the lake could show only a small amount of algae on one sampling date, and due to weather conditions or other factors, an algae bloom could occur the next week. Similarly, the lake may be sampled during an algae bloom, and the phytoplankton populations may be low at other times of the year. July and August are typically the months of the year when algae populations are highest, so sampling during July probably provides a fairly good indication of the maximum growing season algae populations.

Zooplankton are microscopic animals whose movements in a lake are primarily dependent upon water currents. Zooplankton remain suspended in open water. Major groups of zooplankton include protozoa, rotifers and crustaceans. Crustaceans are further divided into copepods and cladocerans (i.e. water fleas). Zooplankton are generally smaller than two millimeters (one-tenth of an inch) in size and primarily feed on algae, other zooplankton, and plant and animal particles. Zooplankton grazing can have a significant impact on phytoplankton species composition and productivity (i.e. biomass) through selective grazing (e.g. size of zooplankton influences what size phytoplankton are consumed) and nutrient recycling. Zooplankton, in turn, are consumed by fish, waterfowl, aquatic insects, and others, thereby playing a vital role in the transfer of energy from phytoplankton to higher trophic levels.

A minimum of two discrete lake water samples were collected from the photic zone of each lake using a horizontal Van Dorn water sampler. The photic zone was defined in this study as a water depth equal to two times the Secchi disk depth. Photic zone discrete samples were then composited together and analyzed for chlorophyll a and used for phytoplankton identification and enumeration. Zooplankton samples were collected by vertically towing a plankton net (80 µm mesh size with a 8-inch orifice) at least two times through the water column. Both phytoplankton and zooplankton identification and enumeration were performed in the laboratory using a Sedgewick-Rafter counting chamber and a microscope equipped with a Whipple Grid. All phytoplankton and zooplankton cell densities (number per volume) were expressed as biomass based on mean cell size.

5.0 Dissolved Oxygen and Temperature

Dissolved oxygen and temperature measurements were taken from the entire water column in the lake using a YSI 610DM dissolved oxygen and temperature meter. Measurements were collected at approximately half-meter intervals.

In late spring or the beginning of summer, deep temperate lakes develop stratified layers of water, with warmer water near the lake's surface (epilimnion) and colder water near the lake's bottom (hypolimnion). As the temperature difference becomes greater between these two water layers, the resistance to mixing increases. Under these circumstances, the epilimnion (top water) is usually oxygen-rich due to photosynthesis and direct inputs from the atmosphere, while the hypolimnion (bottom water) may become depleted of oxygen due to consumption by organisms decomposing organic matter at the lake bottom.

Conversely, shallow temperate lakes may never develop stratified layers of water. For these shallow lake systems, wave action caused by the wind may be sufficient to keep the entire lake completely mixed for most of the year. In shallow lakes, low dissolved oxygen concentrations may occur above the lake sediments even though most of the water in the lake is completely mixed. Therefore, both shallow and deep temperate lakes can have low dissolved oxygen concentrations near the surface of the lake sediments. If low dissolved oxygen levels occur near the lake bottom, sediments may release significant amounts of nutrients (primarily orthophosphorus and ammonia) back into the lake, thereby contributing more nutrients for algae and aquatic plant growth.

6.0 Evaluation of Lake Trophic State

The trophic state of a lake represents its ecological age. Lakes that have excessive levels of phosphorus, phytoplankton (algae), or macrophytes (aquatic plants), or are very turbid are considered eutrophic. This usually means that lake restoration and/or watershed management measures are needed to restore the lake to a more desirable condition. Lakes are classified in this report based on a variety of parameters including total phosphorus (nutrient), chlorophyll a (a measure of algal biomass), phytoplankton type and biomass (actual counting and identifying of algae), water transparency (as measured by the Secchi disk), macrophytes (aquatic plants), and dissolved oxygen. The measured parameters were compared to Environmental Protection Agency (EPA) criteria and calculated Carlson's's Trophic State Indices to classify the lakes and ponds. The United States Environmental Protection Agency delineated parameter ranges for each trophic state in their Clean Lakes Guidance Manual (EPA, 1980). The EPA trophic state ranges are shown in Table 6.1.

Table 6.1
EPA Trophic State Delineation

	Oligotrophic	**Mesotrophic**	**Eutrophic**
Total Phosphorus (µg/L)	<12 µg/L	12 - 25 µg/L	> 25 µg/L
Chlorophyll a (µg/L)	< 2.5 µg/L	2.5 -7 µg/L	> 7 µg/L
Secchi Disk Transparency (m)	> 4.0 m	2.0 - 4.0 m	< 2.0 m

The Carlson's Trophic State Index (TSI) is a method by which measured parameters can be normalized and placed on a scale from 0 to 100. There are several indices that can be used; however, the Carlson's Trophic State Index (TSI) is commonly used in northern lakes that are phosphorus limited, including most New Jersey lakes. TSI values are calculated based on logarithmic equations for total phosphorus, chlorophyll a, and Secchi disk transparency. This index allows lakes to be classified on a continuum, since there is often no clear delineation of trophic state (Carlson's, 1977). However, the trophic state indices calculated using Carlson's methodology can also be used to classify the trophic state of a lake using the delineation shown in Table 6.2.

Table 6.2
Lake Classification Using Trophic State Index

	Oligotrophic	**Mesotrophic**	**Eutrophic**	**Hyper-eutrophic**
Trophic State Index	0 - 40	40 - 50	50 - 65	> 65

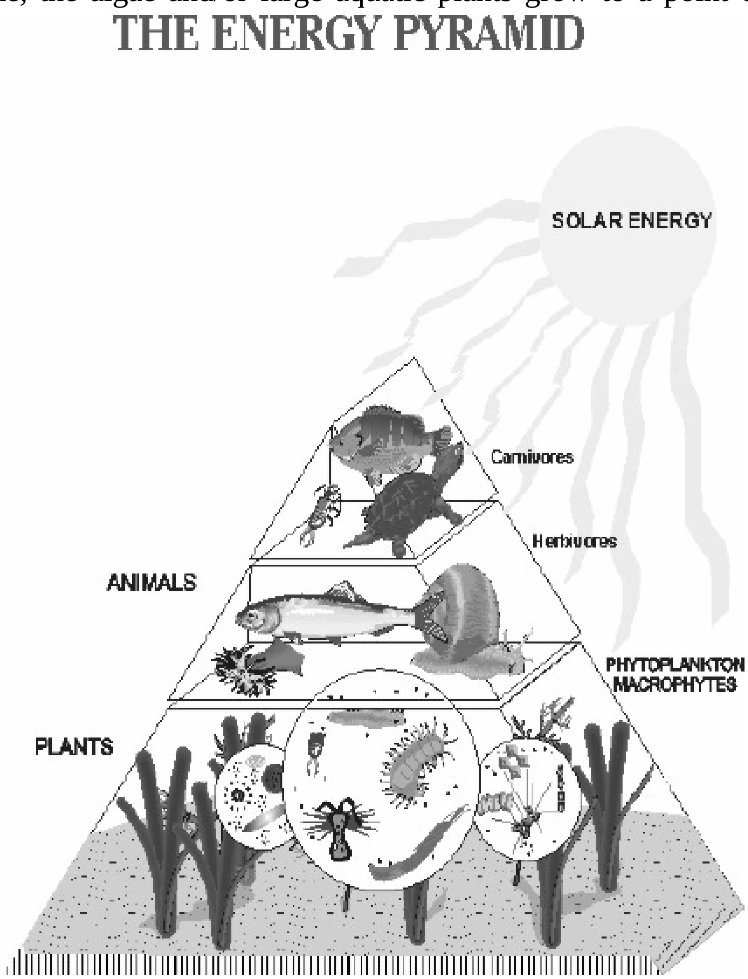
Appendix B
Lake Ecology Primer

Lake Ecology Primer

Ecological Cycle

In a lake, a basic ecological cycle exists. Aquatic plants like algae (microscopic aquatic plants) and macrophytes (large aquatic plants) require nutrients such as phosphorus and nitrogen along with sunlight to grow. Small aquatic animals such as invertebrates (rotifers, protozoa, etc.), snails and insects eat the algae and reproduce. Small forage fish eat the small animals, and, in turn are eaten by larger game fish and other animals. This relationship is called the ecological, or energy pyramid. In a healthy lake, this ecological system exists in proper balance.

When too many nutrients enter a lake, the algae and/or large aquatic plants grow to a point of excess. With a larger population of algae one would expect a nice, large population of fish. However, in reality the excessive plant life is not transferred up the food chain. The small aquatic animals do not eat much of the excess algae (they do not like some of the algae, especially the blue-green algae). Therefore, algae and other plants build up in the lake and destroy the ecological balance of the lake ecosystem. This can result in a reduction in the fish population. It often results in a change in the type of fish found in the lake.



In order to understand the processes that occur in a lake, we must first understand the concept of lake succession or aging.

Lake Succession Over Time

All lakes go through an aging process called ecological succession. Succession is a natural process whereby a lake starts out as an “ecologically” young lake with little vegetation, few nutrients, clear water, and very little unconsolidated (loose) sediment on the bottom. It should be noted that ecological age is different than chronological age. The chronological age is simply the number of years a lake has existed. The ecological age, on the other hand, is a measure of the physical, chemical, and biological conditions of a lake. A lake may be chronologically young (i.e. built only 3 years ago), but it could be ecologically old.

As a lake ages, more nutrients and sediments enter the lake from the surrounding watershed. Usually, the additional nutrients, such as phosphorus and nitrogen, cause an increase in the amount of algae and aquatic weeds. The additional sediment entering the lake settles to the bottom of the lake, increasing the amount of sediment on the lake's bottom.

Thus as a lake ages, it slowly starts to fill up with sediments, algae and aquatic weeds. Initially, the aquatic vegetation is submergent vegetation, beneath the water surface. As the lake fills up further with sediment, emergent vegetation appears above the water surface.

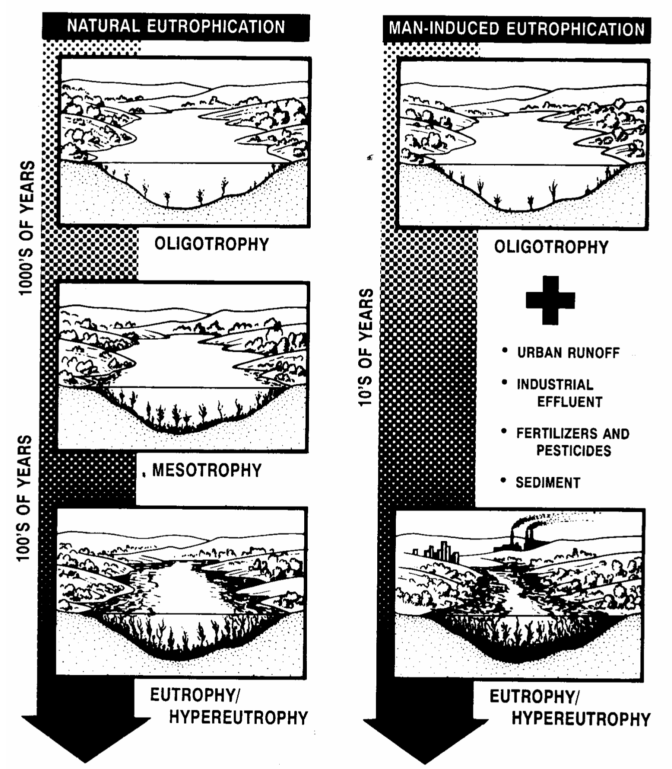
Ultimately, the lake fills in completely with incoming sediment from the watershed and from dying algae, aquatic plants, and animals. The lake transforms into a pond or swamp and eventually, over hundreds or thousands of years, into a forest.

Lake Aging

Lake succession or aging is a natural process that occurs in all lakes. However, the influence of human activities in the watershed can significantly accelerate the aging process.

The lake aging process is accelerated by:

- Wastewater Treatment Plant Discharges
- Malfunctioning Septic Systems
- Agricultural Activities (cropland and pastureland)
- Construction Activities
- Developed Land
- Roadways
- Streambank Erosion
- Landfills



Human activities in a watershed can add sediments and nutrients such as phosphorus and nitrogen to a lake, resulting in accelerated aging or "cultural eutrophication".

Lake Classification

Lakes are classified by the amount of nutrients (or food) contained in the lake. The Greek word for food is "trophic". Therefore, we classify lakes by their "trophic" or food/nutrient state. Such as:

Oligo = little (little nutrients)
Meso = medium (medium nutrients)
Eu = too much (too much nutrients)

The trophic state refers to the “ecological” age of the lake, not its chronological age. Therefore, an oligotrophic lake is a lake that is ecologically young. Lakes are classified by nutrient level and the presence of aquatic plants as described below.

Oligotrophic lake
ecologically young lake
low level of nutrients
low population of algae and aquatic plants

Mesotrophic lake
ecologically middle-aged lake
moderate level of nutrients
moderate population of algae and aquatic plants

Eutrophic lake
ecologically old lake
high leverl of nutrients
high population of algae and aquatic plants

Lake Problems

Excessive nutrients entering a lake from its watershed cause algae blooms, excessive aquatic plants (macrophytes), lake siltation (settling of sediments in lake, loss of lake volume and capacity), and fishery problems (low dissolved oxygen levels change the fish from game fish to trash fish such as carp). This results in loss of recreation and other lake uses, and can reduce property values around the lake.

Lake problems are caused by point sources and nonpoint sources of pollution. Point sources are wastewater treatment plant discharges. Nonpoint sources cannot be traced to a specific origin, but seems to flow from many different sources.
Nonpoint Source Pollution

Nonpoint source pollution involves three natural processes: stormwater runoff, erosion and sedimentation. Rainwater flowing across land and entering rivers and lakes is known as stormwater runoff. The force of runoff breaking up the soils and detaching individual soil particles is termed erosion. The soil particles are eventually deposited into nearby streams and rivers. This process is called sedimentation. Although a natural part of the water cycle, runoff, erosion and sedimentation have been artificially accelerated by the way humans have chosen to develop land, leading to pollution.

Almost all nonpoint source pollution is caused by stormwater runoff and erosion. Leaky septic systems are also considered nonpoint sources. Rainwater and melting snow run over residential lawns, construction projects, streets and farm fields, picking up pollutants such as soil particles, chemicals and nutrients and carrying them into nearby water bodies. Nonpoint source pollution also occurs from infiltration of pollutants into the ground. Pollutants originating from landfills, abandoned mines, underground storage tanks and septic tanks are possible groundwater pollution sources.

Lake and Watershed Management

A watershed is that area of land that drains directly into a lake, either through rivers, streams, surface runoff, or groundwater. A watershed is best envisioned as a funnel with a glass at the bottom representing a lake. Anything that falls into the funnel will find its way into the glass. Much the same occurs in a watershed, therefore watershed characteristics such as size, land use, slope, and soils play an important role in determining both the quality and quantity of the water that drains to a lake. For this reason, getting to know a lake's watershed and the activities that go on in the watershed are of primary concern to the individuals that manage and enjoy the lake.

Lake management refers to the practice of maintaining lake quality such that attainable lake uses can be achieved (Jones et. al, 2001). Management of a lake is integrally related to management of the surrounding watershed. Watershed management is the process of protecting the lakes, streams, and wetlands in the watershed from point and nonpoint source pollution. It is accomplished by developing an understanding of key factors that affect the water quality of lakes, streams and wetlands and by following a plan of action to prevent, reduce, or minimize those activities within a watershed that may negatively impact water quality. Watershed management consists of many diverse activities including controlling point and nonpoint source pollution, monitoring water quality, adopting ordinances and policies, educating stakeholders, and controlling growth and development in a watershed.

Lake Protection and Restoration

Depending on the physical traits of the lake and watershed, and the quality of the incoming water, certain lakes are suited for particular uses. It can sometimes be difficult to manage a lake for conflicting uses; for example, trout fishing and motorboat racing. A lake cannot be all things to all people, and it can be difficult and expensive to force a lake to support a specific use when it is unrealistic to do so. It is important, therefore, when undergoing a lake protection or restoration project, to set specific goals that are based on a thorough investigation of the lake and its watershed. Lake protection is defined as "The act of preventing degradation or deterioration of attainable lake uses." Lake protection projects are usually undertaken by municipalities or lake associations who fear their lake will suffer from the adverse effects of encroaching development. Lake restoration refers to the act of bringing a lake back to its attainable uses (Jones, et. al., 2001). It is important to be realistic in one's expectations for lake restoration. Nonpoint sources of pollution in a watershed can be difficult to detect and control, and without proper watershed management, lake restoration efforts can fail. A comprehensive watershed management plan should be designed and implemented involving as many watershed stakeholders as possible for best success in lake restoration projects. In any lake project, educating watershed citizens about how their activities affect the lake can be extremely helpful.

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Appendix C
New Brooklyn Lake
Water Quality Data
Phytoplankton Data
Zooplankton Data